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Health Risk Assessment of Polychlorinated Biphenyls (PCBs) in Classroom and Office Dust Samples from Federal University in Abeokuta, Nigeria

Anselm Oluwaseun H[1], Badeji Abosede A. [1], Salaudeen Aishat[1], Olagbuyiro Iyanuoluwa M.[2], Osinubi Adejoke D. [1] and Ameen Hammed O. [1]

[1]Department of Chemical Sciences, Tai Solarin University of Education, Ijagun
[2]Department of Research, Ace Initiative for Sustainable Development

Corresponding Author: anselmoh@tasued.edu.ng

ABSTRACT

Polychlorinated biphenyls, also known as PCBs are organochlorine compounds that were commonly applied by industries including agriculture. This study determined the concentrations of 28 PCB congeners in dust samples obtained from offices and classrooms of Federal University of Agriculture in Abeokuta, Nigeria, using gas chromatography-mass spectroscopy (GC-MS). The results revealed that the dust samples collected from the classroom had higher PCB concentrations with a total concentration of 102.02 ng/g and mean concentration of 5.36 ng/g, while dust samples from the offices had a total PCB concentration of 87.22 ng/g with a mean concentration of 3.35 ng/g. For dust samples collected from offices, PCB-52 had the lowest concentration (0.77 ng/g) and PCB-81 had the highest concentration of 8.98 ng/g. For dust samples collected from classrooms, PCB-101 had the lowest concentration of 0.47 ng/g, while the maximum concentration of 23.51 ng/g was noted in PCB-189. The HQ of but samples were >1. Hence, this study suggests that further investigation is needed to determine the variation in concentrations of PCBs in other locations within the school with more focus on specific PCB sources and exposure pathways.

Keywords: Health risk, Polychlorinated biphenyls (PCBs), university dust, GC-MS

INTRODUCTION

Polychlorinated biphenyls, also known as PCBs, with general molecular formula $C_{12}H_{10}{-}xCl_x$ are manufactured chemicals which have never been found in nature until the 1900s when companies and consumers started to release them into the environment (Ayri, 2021). They contain 1–10 chlorine atoms as substituents on biphenyl and congeners, which were commonly produced in a mix of between 60 and 90 different congeners and are made up of 209 distinct types of chlorine biphenyl rings (Qiu et al., 2017). Under the Stockholm Convention, these compounds fall into a category of industrial chemicals classified as persistent organic pollutants (POPs), which are bio-accumulative and toxic (Mishra et al., 2022). They are used in the manufacture of electric transformers, capacitor fluids, flame retardants, hydraulic lubricants, rubber, and plastics, to mention a few (Lawson et al., 2021). Accidental leakages, transportation leaks, PCB-containing transformers fires, and river input from unregulated industrial or municipal discharges are ways by which they enter the soil and water (Ajagbe et al., 2018).

Polychlorinated biphenyls are exceptionally alluring as they have been utilised for various mechanical purposes since they are non-reactive and safe for combustion (Ludwig, 2013). The source of PCBs in developing nations like Nigeria has been ascribed primarily to the importation of PCB-containing materials such as transformers, capacitors of electrical gear, and a few ordinary items (Gioia et al., 2014; Okoh, 2015). In the long run, PCBs and a few other natural and inorganic contaminants are discharged into the soil and other natural compartments. Owing to their long-range atmospheric transport (LRAT), Polychlorinated biphenyls are transported for long separations and have been recognised within the farthest corners of the globe, contaminating places distant from where they were discharged (Dziubanek et al., 2017; Liu et al., 2013).

The effects of PCBs on the health of humans are numerous. These effects include cancer, neurological, immune and reproductive damage, endocrine disruption, lower IQ and birth defects (Van der Oost et al., 2003). In an attempt to get rid of the chemicals, laws such as Toxic Substances Control Act and Stockholm Convention were made to stop their production (Melymuk et al., 2022). They nonetheless remain present in the immediate environment as they are very persistent (Gouin et al., 2005).

The study of PCBs in the soil is therefore important because the soil is a big storehouse for these harmful chemicals. Moreover, soil plays a crucial role in how PCBs are transported globally and passed along the food chain (Dang et al., 2010). Universities in Nigeria are densely populated; hence a large number of wastes are generated, which are mostly discarded by open incineration. Oil leakages from transformers as well as emissions from generating sets, are some of the activities that leak PCBs into the soil (Sun et al., 2016). Though PCBs have been analysed in Nigerian soil such as from urban areas in Lagos, soil and dust from electric power stations and composite soil (Alani et al., 2013; Fatunsin et al., 2019; Folarin et al., 2018). There is a dearth of literature on PCBs in university soils and dust. Hence this study aims to determine the total PCB concentrations in dust samples from classrooms and offices in a typical Nigerian University. Hence the Federal University of Agriculture was selected for a pilot study, this is because being an institution with focus on Agriculture, there may be possible use of pesticides or herbicides that other universities. Of which these pesticides and herbicides are known sources of PCBs in the environment (Rajmohan et al., 2020).

MATERIALS AND METHODS

Sampling

Paintbrushes were pre-cleaned with hexane and air-dried. Afterwards, dust from elevated places in four offices and classrooms in the Federal University of Agriculture Abeokuta were collected with pre-cleaned paintbrushes. this was done by sweeping the dust into an aluminum foil and wrapped after collected. The wrapped samples were kept in cold containers at -4 °C and transported to the laboratory were dried and sieved before being analysed.

Soil Sample Extraction and Clean-up

Polychlorinated were extracted from the collected dust samples using ultrasonic waves using the U.S. Environmental Protection Agency, USEPA 8280 method. A 10 g of the sample was mixed with 10 grams of anhydrous Na_2SO_4. A small amount of a mixture of dichloromethane (DCM) and n-hexane was added to the mixture, and then it was shaken with sound waves for 15 minutes at a temperature of 35 °C. The procedure was repeated two times using new parts of the liquid mixture on the leftover substance during each repetition. The extracts were collected and then passed through a small filter. After that, they were made more concentrated using a machine that evaporates the liquid. Finally, they were cleaned up using a column filled with silica gel. A small amount (30 mL) of a mixture of 1 part DCM and 1 part n-hexane

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was used to remove PCBs from the column. The resulting liquid was made more concentrated (1 mL) using a slow stream of nitrogen gas.

Instrumental Analysis

All samples were analysed for PCBs using GC-MS (Agilent 6890N and Agilent 5975B).

Samples were injected at 280 °C and 300 °C for injecting and detecting them, respectively. The starting temperature of the column was 80 °C. It stayed at that temperature for 2 minutes, then increased to 180 °C at a rate of 10 °C per minute. It then went up to 280 °C at a rate of 5 °C per minute and stayed there for 20 minutes. The gas in the carrier had a pressure of 70. 06 kPa and was moving at an average speed of 31. 54 cm/s. The Gas chromatograph received a small amount of the sample through a special method called pulsed splitless mode. The amount of the sample injected was 4 µL.

Health Risk Assessment

Toxicity

Toxicity Equivalence Quotient (TEQ) was used to determine the toxicity of each dioxin-like (DL) polychlorinated biphenyl found in the dust sample. the TEQ was obtained using the equation (eq),

$TEQ = C\,x\,TEF$ .... eq (i)

Where C is the concentration of each DL PCB and TEF is the Toxicity Equivalence Factor of the dioxin-like polychlorinated biphenyl.

Incremental lifetime cancer risk (ILCR) and hazard quotient (HQ) index

The ILCR and HQ which is non-carcinogenic risk were determined for adults only, as the people within the study area were predominantly adults, and it was calculated for all the PCBs (DL and non-DL) exposure through indeliberate ingestion of dust, inhalation, and dermal contact using the formulas in eq. (ii), (iii) and (iv), and HQ was calculated using the formula in Equation (v) (USEPA, 1989).

$$ILCR_{inh} = \frac{C\,x\,IR\,x\,ED \times EF\,x\,\;CFx\,SFO}{AT\,x\,BW} \text{ eq. (iii)}$$

$$ILCR_{inh} = \frac{C\,x\,IhR\,x\,ED \times EF\,x\,CF\,x\,IUR}{AT\,x\,BW} \text{ eq. (iii)}$$

$$ILCR_{derm} = \frac{C \times SA \times AF \times ABSd \times ED \times EF \times CF \times SFO \times GIABS}{AT\,x\,BW} \quad \text{eq. (iv)}$$

$$HQ = \frac{C \times IR \times ED \times EF \times CF}{AT\,x\,BW\,x\,RfD} \qquad \text{eq. (v)}$$

Where C is the total concentration of all the PCBs present in the dust sample, which is 87.22 ng/g for the office sample and 102.02 ng/g for the classroom sample; surface area (SA) of the skin exposed is 3300 cm^2 for adults; AF is soil/dust adherence factor which is 0.7 mg cm^{-2} for adults (Famuyiwa and Entwistle, 2021). The inhalation rate (IhR) used was 20 m^3/day for adults; the ingestion rate (IR) for adult is (100mg/d). Dermal absorption factor (ABS$_d$) is 0.1; Exposure duration (ED) is approximately (53 years); Exposure frequency (EF) is 350 days/year; PCB Oral slope factor (SFO) is 2 mg/kg d; inhalation unit risk (IUR) is (5.7 *10^{-1} µg m^{-3}); Adult body weight (BW) is 70 kg; Reference dose (RfD) of PCBs (3.3 * 10^{-5} mg kg^{-1} d^{-1}); Average exposure time (AT) is 25,550 days, Gastrointestinal absorption factor (GIABS) is

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1; Conversion factor (CF) is 1* 10^{-6} (Francisco et al., 2017).

RESULTS AND DISCUSSION

A total of 28 congeners were found in the samples. For office samples the range of the PCB concentration is 0.98 ng/g to 8.98 ng/g, while the sum of PCBs in the classroom samples is 102.02 ng/g with a mean of 5.36 ng/g as shown in Figure 1. For dust samples collected from offices, PCB 52 has the lowest concentration of 0.77 ng/g, and a maximum concentration of 8.98 ng/g was found in PCB 81. For dust samples collected from classrooms, PCB-101 recorded the lowest concentration of 0.47 ng/g, while PCB 189 recorded the maximum concentration of 23.51 ng/g. PCB 8 and PCB 18 were absent in samples collected from offices, while PCB 8, PCB 18, PCB 44, PCB 52, PCB 66, PCB 123, PCB 153, PCB 157, and PCB 170 were missing in dust samples collected in classrooms. The PCB congeners concentration recorded in the classroom samples is higher than the values recorded from offices except for PCB 77, 101, 126, 128, 138, 156, 169, 180, and 195.

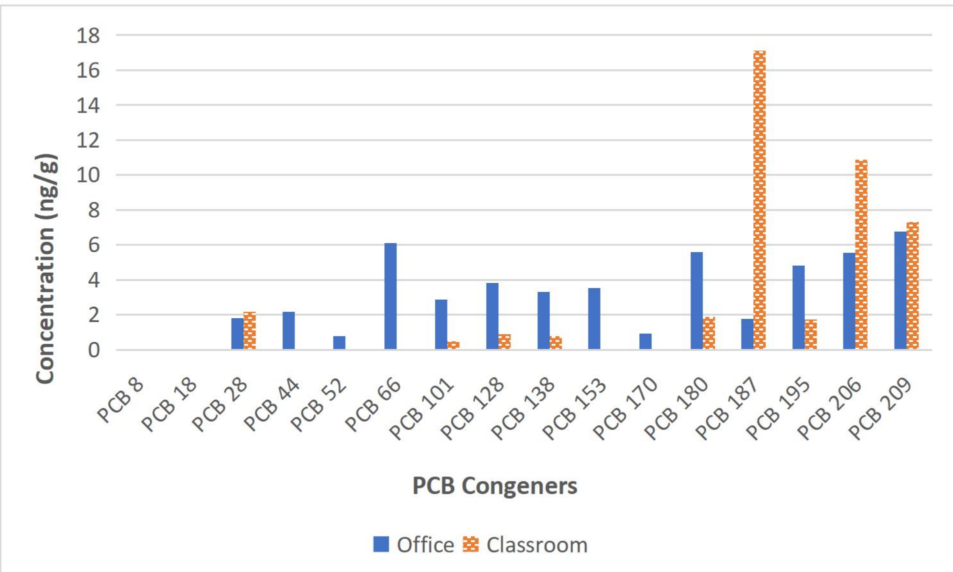

Figure 1. Concentrations of PCBs (ng/g) in the dust samples.

The concentrations of PCB in dust samples in this study were high, this may be because organic carbon levels can change a lot, and the dust can be affected by recent and different amounts of particles in the air. The PCBs in the dust can more easily get into foods and crops, which can make people more likely to be exposed to them. The values of PCBs in the dust samples collected in the office were low compared to dust samples collected in classrooms. The total PCB ranged from 87.22 ng/g (office) to 102.02 ng/g (classrooms), while the mean ranged from 3.35 ng/g (offices) to 5.36 ng/g (classrooms). This study found that the classrooms were more polluted with higher concentrations of PCBs; having a total concentration of 102.02 ng/g and an average concentration of 5.36 ng/g. The elevated levels in classrooms could be attributed to factors such as older building materials, poor ventilation, or higher human activity (Bluyssen, 2017). This may also be due to the population of students who can easily transfer the PCBs congeners from different locations in

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the institution. The variability in individual PCB congeners may reflect different sources or degradation processes (Strémy et al., 2019). However, the presence of higher-chlorinated PCBs (e.g., PCB-209) indicates potential ongoing contamination sources, as these are less prone to environmental degradation (Mastin et al., 2022).

The total PCB concentration recorded in this study were significantly higher than the PCBs of 17.60 ng/ng and 82.0 ng/g recorded in different sites in Bariga Lagos by Fatunsin et al. (2019). It was also higher than the value reported by Pelitli et al. (2015) from Russia, Sandanger et al. (2004) from Alaska, Bentum et al. (2016) from Ghana and Al-Haddad et al. (1993) from Bahrain as shown in Table 1. However, the value recorded in this study is lower than 224.18 ng/g and 122.8 ng/g found in power stations in Lagos state by Folarin et al. (2018). The total PCB concentrations in all the dust samples were also lower than the 25000 ng/g and 33000 ng/g recommended levels for soil, as stated by USEPA and CCME (1999). This implied that the reported concentrations of PCBs in the present study is not too high; hence the chances of posing a risk to the inhabitants of the sampling sites are low.

Table 1: Comparison of the Concentration (ng/g) of polychlorinated biphenyls in this study with previous studies

Study	Mean concentrations (ng/g)	Total concentrations (ng/g)
This study	3.35 ± 2.12 (Offices) 5.36 ± 5.89 (Classrooms)	0.77 - 8.98 (offices) 0.47 - 23.51 (classrooms)
Al-Haddad et al. (1993)	0.2 -72.7	-
Pelitli et al. (2015)	50.48	0.06 - 150
Bentum et al. (2016)	0.83 – 2.27	7.55 – 9.15
Folarin 2018	3.8 - 52 (dust)	21 – 2200 (dust)
Fatunsin et al. (2019)	1.25 - 4.8	17.60 - 82

Twelve (12) out of the Twenty-eight (28) PCB congeners found in the office and classroom dust samples were dioxin-like, while the remaining fourteen (16) were non-dioxin-like. Figure 2 is a representation of the DL PCB found in the office and the classroom samples while Table 2 shows the results of the TEQ. The PCB with the most TEQ is PCB 126, with a value of 0.381 ng/g for the office sample and 0.88 ng/g for the classroom sample. The PCB with the least TEQ is PCB 118 in the office sample ($3.30 * 10^{-5}$ ng/g) and PCB 156 in the classroom sample ($2.10 * 10^{-5}$ ng/g). Meanwhile, non-dioxin PCBs has a concentration range of $0.43 * 10^{-4}$ to $3.21 * 10^{-1}$ in the office dusts and the classroom sample ranges from $6.30 * 10^{-5}$ ng/g to $2.25 * 10^{-2}$ ng/g in the classroom dust. The classroom has a higher Total Toxicity Equivalence Quotient (TTEQ) value of $9.07 * 10^{-1}$ ng/g with a mean value of $3.21 * 10^{-2}$ ng/g, while the office has a TTEQ value of $4.17 * 10^{-1}$ ng/g with a mean value of $9.07 * 10^{-2}$ ng/g.

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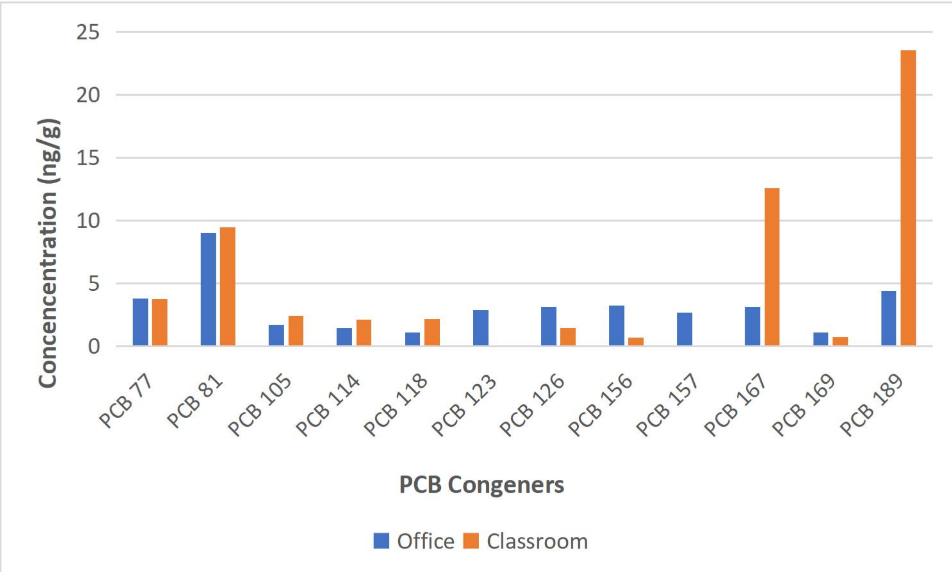

Figure 2: Concentrations of Dioxin-like PCBs found in the samples.

Table 2: Total Equivalence Quotient of the Dioxin-like (DL) PCBs

CONGENER	TEQ (ng/g)	
	OFFICE	CLASSROOM
PCB 77	$3.78 * 10^{-4}$	$3.75 * 10^{-4}$
PCB 81	$2.69 * 10^{-3}$	$2.84 * 10^{-3}$
PCB 105	$5.10 * 10^{-5}$	$7.20 * 10^{-5}$
PCB 114	$4.30 * 10^{-5}$	$6.30 * 10^{-5}$
PCB 118	$3.30 * 10^{-5}$	$6.60 * 10^{-5}$
PCB 123	$8.60 * 10^{-5}$	N.D
PCB 126	$3.81 * 10^{-1}$	$8.80 * 10^{-1}$
PCB 156	$9.80 * 10^{-5}$	$2.10 * 10^{-5}$
PCB 157	$8.00 * 10^{-5}$	N.D
PCB 167	$9.40 * 10^{-5}$	$3.77 * 10^{-4}$
PCB 169	$3.21 * 10^{-2}$	$2.25 * 10^{-2}$
PCB 189	$1.32 * 10^{-4}$	$7.05 * 10^{-4}$
TTEQs	$4.17 * 10^{-1}$	$9.07 * 10^{-1}$

The results of the ILCR and HQ are shown in Table 3. The value of ILCR for inhalation for the office sample was within the acceptable range of $1 * 10^{-6}$ to $1 * 10^{-4}$, while the values of ILCR for accidental ingestion and dermal contact for the office sample were above the acceptable limit. The value of ILCR for inhalation for the classroom sample was within the acceptable range of $1*10^{-6}$ to $1 * 10^{-4}$, while the values of ILCR for accidental ingestion and dermal contact for the classroom sample were above the acceptable range. The value of the non-carcinogenic risk, HQ for office sample was 2.7413 and that of the classroom was 3.2065 which were both higher than the acceptable limit of 1 (Famuyiwa and Entwistle, 2021).

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Table 3: Evaluated ILCRs and HQ for Adults

	$ILCR_{ing}$	$ILCR_{inh}$	$ILCR_{derm}$	HQ
Offices	$1.81 * 10^{-4}$	$1.0 * 10^{-5}$	$4.18 * 10^{-4}$	2.7413
Classrooms	$2.12 * * 10^{-4}$	$1.2 * 10^{-5}$	$4.89 * 10^{-4}$	3.2065
Mean	$1.96 * * 10^{-4}$	$1.1 * 10^{-5}$	$4.35 * 10^{-4}$	2.9739

Generally, all the values of the carcinogenic risk (ILCR) for accidental ingestion, inhalation, and dermal contact, as well as the non-carcinogenic risk (HQ) for the classroom samples were higher than the values found in the office samples. This might be because classes are mostly opened with wider doors and sometimes missing windows, unlike offices which sometimes have air conditioners with lesser exposure to external environmental influences.

CONCLUSION

Polychlorinated biphenyls were found in all the offices and classrooms dust samples were collected. The presence of PCBs in the environment can eventually lead to several health complications in humans. This is because they are persistent in the environment and human bodies upon exposure. The concentrations of PCBs in the office and classroom in this study were not very high. However, because PCBs persist in the environment for a long time, there is a chance that they could cause health problems if people are exposed to them for a long period. This research suggests that future studies are required to understand the different levels of PCBs in other parts of the school, especially in areas near transformer installation. Therefore, further investigation into specific PCB sources and exposure pathways is warranted to assess potential health risks. Also, proper monitoring of oil discharged from transformers and electric appliances should be done, and waste should be removed following regulations. In addition, PCB testing should be done for caulks, paints, and building materials used in schools. The use of vacuums with high-efficiency particulate air filters (HEPA) to eliminate up to 99.97% dirt, dust, pollens and other pollutants is also highly recommended.

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